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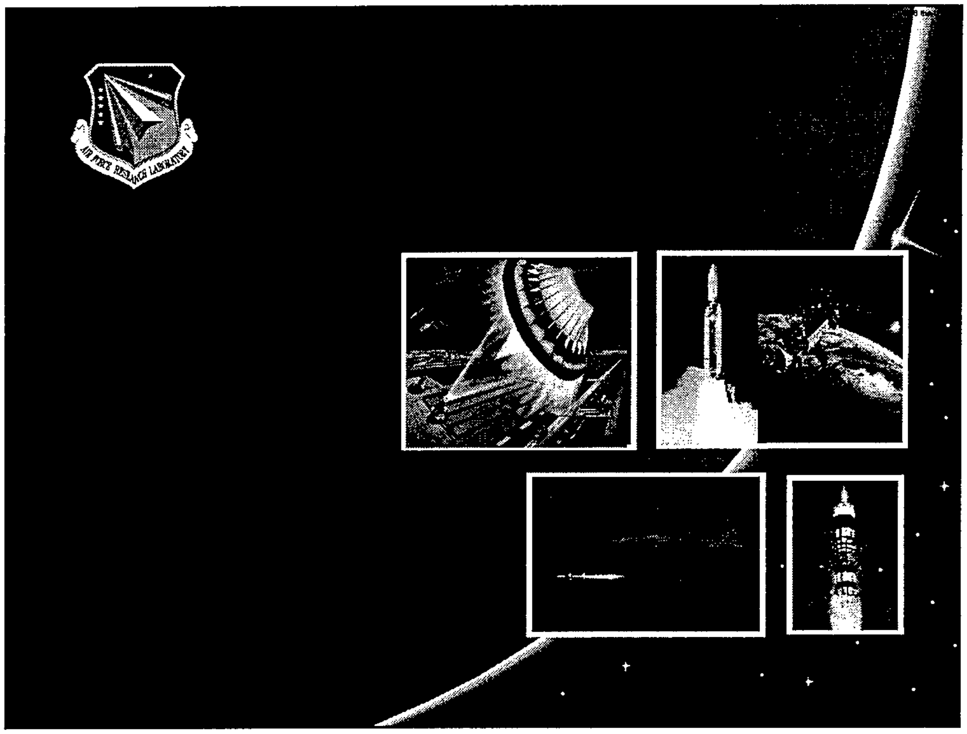
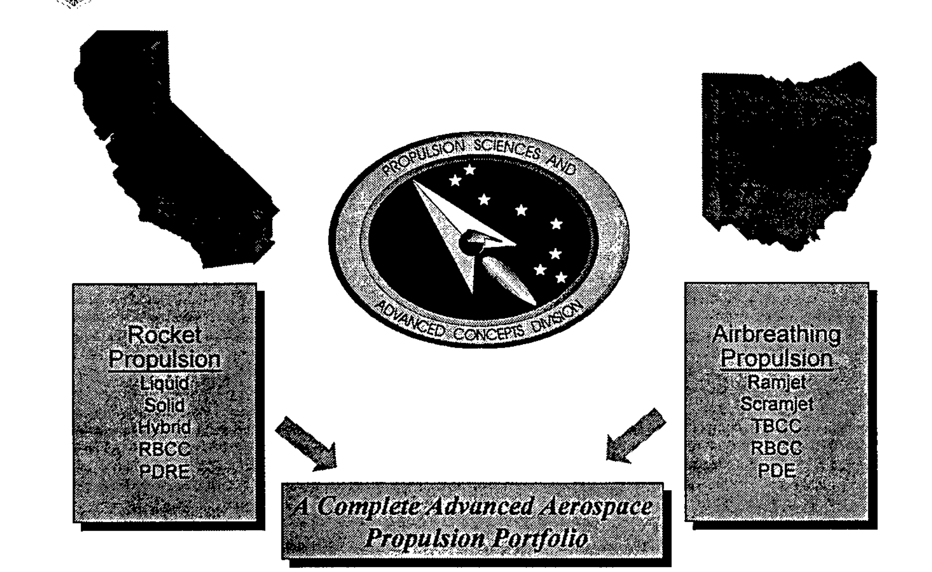
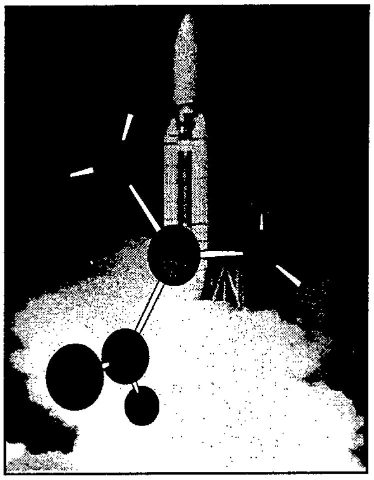
41 items enclosed



Comprehensive Advanced Propulsion Research



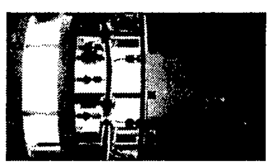
Technical Specialties



- Combustion
- Hypersonics
- Fuels and propellants
- Lubricants and mechanical systems
- Advanced components
- Advanced-concept system analysis
- Plume phenomenology

Trapped Vortex Combustor

6.1



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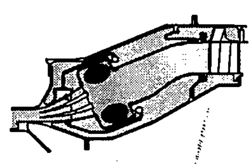


6.3

ESTIMATED ADVANTAGES

- 35% Reduction in Cost
- 3.0% Reduction in Specific Fuel Consumption
- 25% Reduction in Combustor Weight
- 30% Increase in Altitude Relight
- Factor of 10 Reduction in Lean Blow Out Limit
- Factor of 20 Reduction in NOx

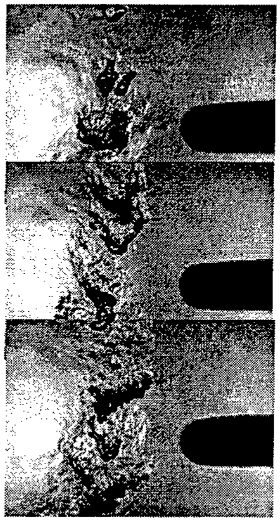
TECHNICAL CHALLENGES

- High performance & acceptable pollutant emissions
- Flame stability
  - ★ Maintain flame stability at higher combustor flow velocities (>100ft / sec)
- Rapid fuel-air mixing
  - ★ Requires revolutionary mixing techniques

STATUS / PROGRESS

- Preliminary modeling & experiments conducted
  - ★ Excellent performance even at high velocities (>500ft / sec)
  - ★ NOx emissions far below current technology designs
- Significant potential as a major step forward
  - ★ General Electric Aircraft Engines to pursue development

Supercritical Combustion



Transcritical Oxygen Drops in Nitrogen

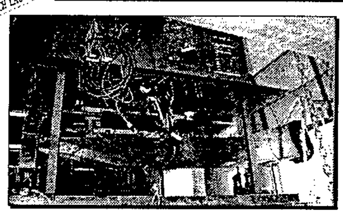
PROBLEM

High-performance rocket and airbreathing engines operate in high-temperature/pressure "supercritical" fluid regime where surface tension vanishes, leading to unpredictable injection and combustion that must be corrected by trial and error

OBJECTIVE

Determine the mechanisms that control the breakup, transport, mixing, and combustion of supercritical droplets, jets, and sprays, so future engines may be designed "right the first time"

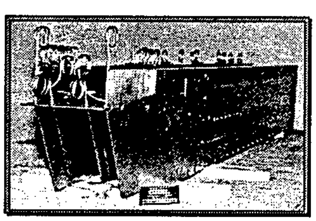
HyTech Program

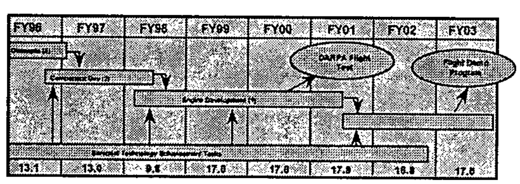


"Advanced cycle, dual mode ramjet/scramjet engines, and high temperature, lighter weight materials which allow for long range, long endurance, high altitude supercruise are the enabling technologies."

Develop/Demonstrate H/C SCRJ Technology
- Performance: Mach 4-8
- Durability: 12 Minute
- Maturity: TRL 6 (System in Relevant Environment)

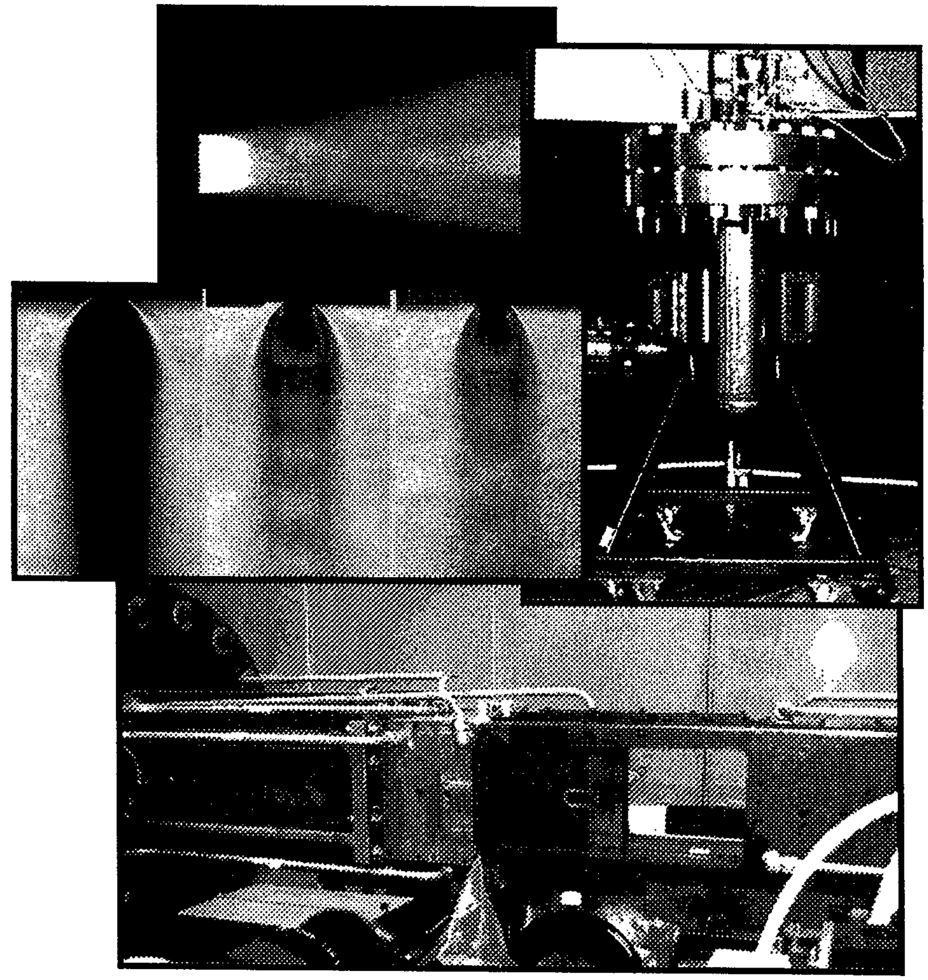
Transition opportunity
- DARPA Affordable Rapid Response Missile Demo (Heavy - fixed Mach)
- AFRL/MN Time Critical Target Technology
- Demo Program (Full function engine)
- Fast Reaction Stand-off Weapon Pgm





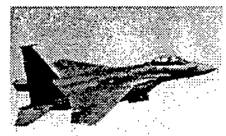
Ram/Scramjet Research

- Available Facilities
  - Water-Cooled Combustor
  - Fuel Injection Tunnel
  - Direct-Connect Thrust Stand
    - Ducted Rocket
    - Scramjet
  - Supercritical Injection Chamber
- Supersonic Combustor under Development
  - Currently configured for M = 1.8 crossflow
  - Ethylene fueled vitiator limited to 150 psia
  - Nominal flowpath cross section dimensions: 1.5" x 4.0"
  - Well instrumented, accessible for optical diagnostics



Fuels and Lubrication Objectives

- HIGHER HEAT SINK FUELS
  - Improve Aircraft Thermal Management
  - Reduce Fuel System/Engine Fouling
  - Reduce O&M Costs
- IMPROVED COMBUSTION
  - Reduce Development Time and Risk (Cost)
  - Expand Engine Performance Envelope
  - Reduce Atmospheric Pollution
- IMPROVED LUBRICATION SYSTEMS
  - Longer Life, Higher Temperature Lubes
  - Reduce Weight/Life Cycle Cost
  - Increase Speed/Temperature Capability
  - Corrosion Resistant Bearings

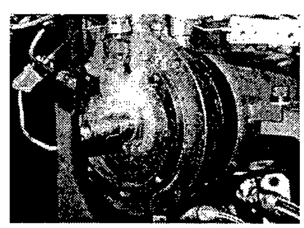


SYSTEM PAYOFF
- Improved Reliability
- Lower Life Cycle Cost
- Improved Performance
- Reduced Env'l Impact

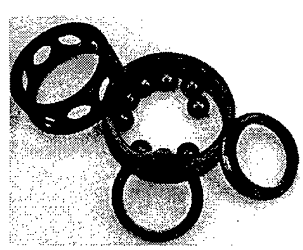
Vapor Phase Lubrication

Demonstrated, for First Time, Sustained Operation at Gas Turbine Conditions w/o Liquid Lubrication

KEY TECHNOLOGIES:
- Deposition & Condensate Lubricant (TBPP)
- Carbon-Carbon Composite Cage
- Solid Lubricant Coating
- Oil Mist Delivery
- Computer Modeling and Design



PAYOFFS (Limited Life Engine):
- 90% Reduction in Lube System Weight
- 15% Reduction in Engine Cost
- Higher Temperature Capability (204à 650°C)



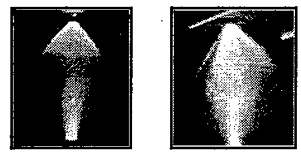
Auxiliary Support for Magnetic Bearings!

"JP-8+100"

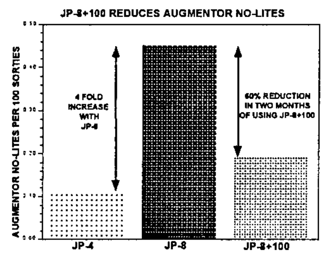
Improved Thermal Stability Fuel

WHAT IS JP-8+100?

- JP-8 With Thermal Stability Additive Package
  - Antioxidant
  - Metal Deactivator
  - Detergent
  - Dispersant
  - Added at 100 - 300 ppm
- +100°F Increase in Stability
  - Bulk Temp: 325°F to 425°F
  - Wetted Wall Temp: 400°F to 500°F
- Cost Goal: $0.001/gallon
  - $1.50 to Fill Up F-15
- Specification By FY99
  - Worldwide Use



- *Coking/Fouling/Sooting Distorts Spray*
- *Causes Engine Hot Streaks and Damage*
- *Contributes to High Cycle Fatigue*

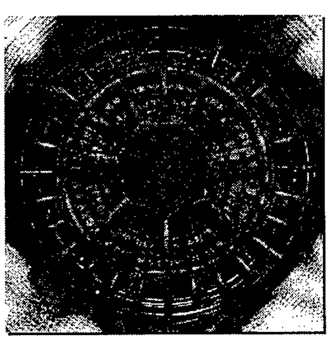


T-38 aircraft at Sheppard AFB TX

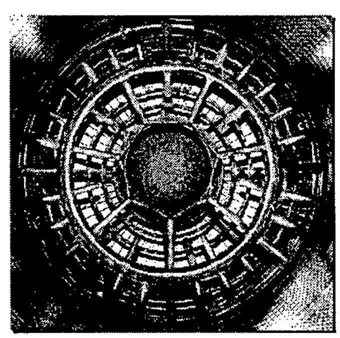
JP-8+100 Demonstration

Kingsley Field, OR (F16/F100-200)

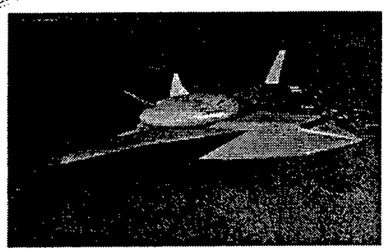
200+ Hours on JP-8



200+ Hours on JP-8
then
56 Hours on JP-8+100



Advanced Monopropellants

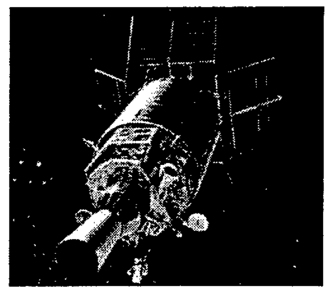


Description:
Monopropellants for high performance, simple, easy to use, highly maneuverable military space vehicle

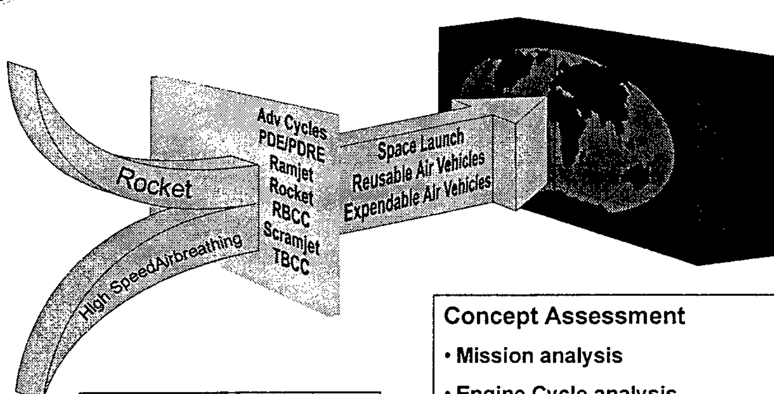
- Single propellant for entire vehicle
- Eliminates one pumping system
- Eliminates cryogenic storage/use
- Enables airplane-like operations

Payoff:

- Simple propulsion system
- On-demand launch
- Any orbit or inclination virtually anywhere on earth
- Take off anywhere, land anywhere
- Easy to load
- Non-toxic replacement for hydrazine
- Double satellite on-orbit lifetime



Full-Spectrum Research and Integrated Vehicle/Propulsion Assessments



Concept Assessment

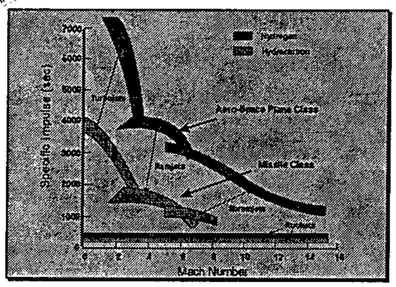
- **Mission analysis**
- **Engine Cycle analysis**
- **Tool development & modification**

Enabling Technologies

- **Lightweight materials**
- **Advanced propellants**
- **Injection & combustion**

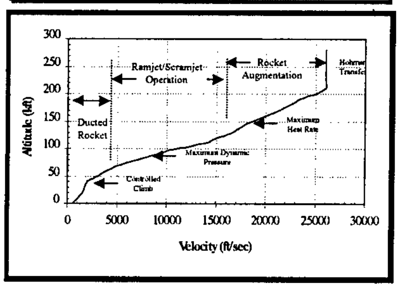
One-stop "global" propulsion research & analysis

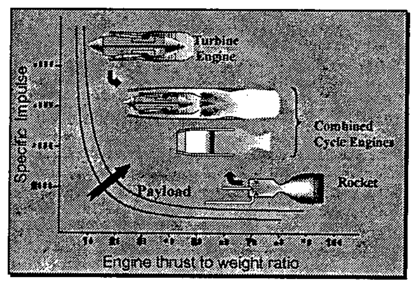
Integrated Propulsion for Space



Bridge Air & Space

- Move to aircraft-like operations
- Global reach in 2 hours or less
- Bootstrap to spacelift

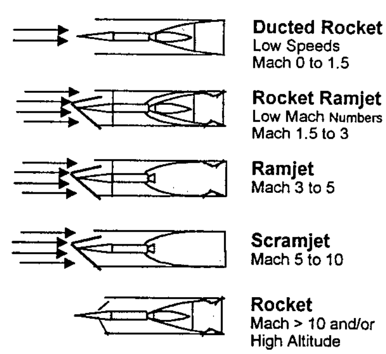




Rocket-Based Combined Cycle

Payoff

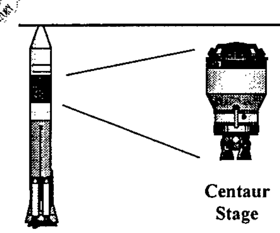
- Enables space launch systems that can deliver payloads for 10% of current costs
- Enables a broad range of military transatmospheric applications
  - Global Reach Reconnaissance
  - Force Application
  - Space Control



Space Lift Concepts

- **RBCC TSTO:** HyperSoar
- **LACE TSTO:** Space Access
- **Launch Assist:** Pioneer RocketPlane, RASV, KST Astroliner, Maglev, X-34
  - Air Launch
  - Rail Launch
- **Rocket Recoverable TSTO:** Kistler K-1
- **MSP Pop-Up:** RLV / X-33 Derived
- **Rocket SSTO:** RLV
- **RBCC SSTO:** NASP, Vision, Trailblazer

Performance Improvements Due To:



Centaur Stage

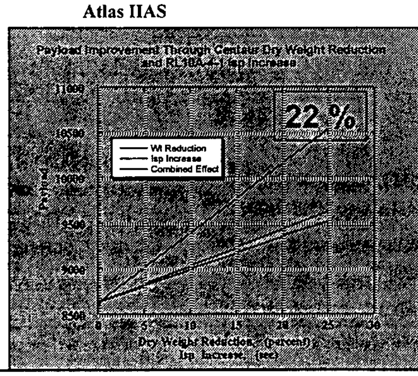
Atlas IIAS

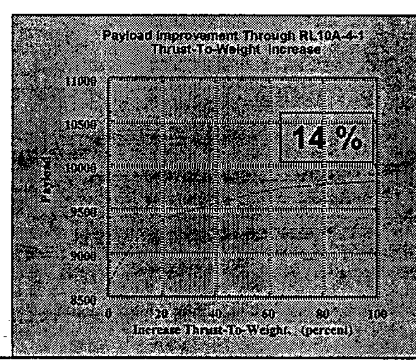
1) **Weight Reduction**
2) **Increased Engine Specific Impulse**
3) **Increased Engine Thrust-To-Weight**

Baseline Payload (GTO Mission) <u>8625 lb_m</u>

$$\Delta V = g_0 Isp \ln\left[\frac{m_0}{m_f}\right]$$

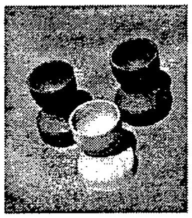
m_o = initial stage mass, lbm
m_f = final stage mass
Isp = engine specific impulse
g_0 = gravitational constant



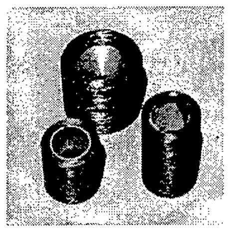


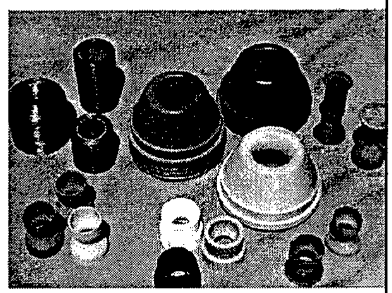
Inverse-Processed Nozzles/Throats/Chambers

Innovation Enables High-Performance Designs



Production Steps
1) Spray/Cast/Machine Liner
2) Fiber Wrap/Braid
3) Densify C-C

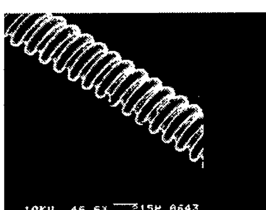




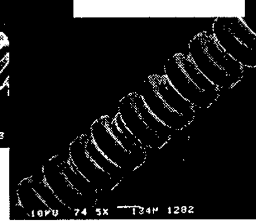
Payoff:

- Liquids: 4000 °F radiation cooled, oxidation resistant nozzles increase booster thrust-to-weight 15% (RL-10)
- Spacecraft: Long-life (>10 hr) rhenium-lined C-C thrusters at 10% the cost
- Tactical: Erosionless throat increases AMRAAM delivered Isp by 6 sec

Microdevice Fabrication and Micropropulsion

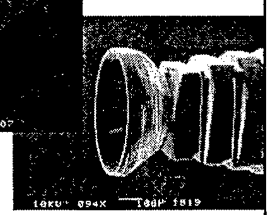


Heat Exchangers



Pressure and Temperature Sensors

Ducts & Valving



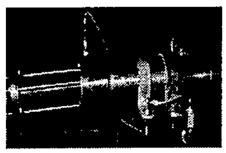
Microthrusters

- **Revolutionary method can make any 3-D micron scale shape from any material--1st reliable 3-D manufacturing method**
- **Will enable ultra-small satellites for sensing & exploration missions**
- **Thousands of micro-sensors can be imbedded in propulsion system components--enabling huge increases in system reliability**

Plastics for Rockets

Crucial to Reducing Weight and Cost

Liquid Rocket Engines



Polymer Tube/Case Hot Gas Burst Tester

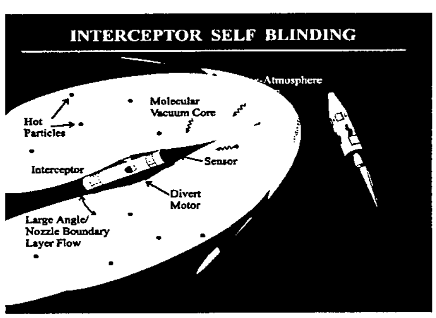
Plastic Engine Ducting (SSME)
- 80% duct weight decrease
- 15% upper stage thrust-to-weight increase

Solid Rocket Motors

Char Motor Polymer Insulation Samples

50% Lower Erosion Insulation
- Cuts Booster Insulation weight 44%
- Increases Booster Payload 7.4%

Missile Plume Signatures



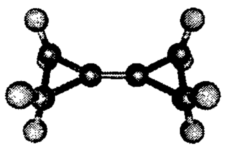
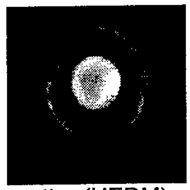
Payoff

- **Improved Discrimination with Countermeasures**
- **Reliable - All Weather Detection & Tracking**
- **Robust Boost Phase Intercept Capability**

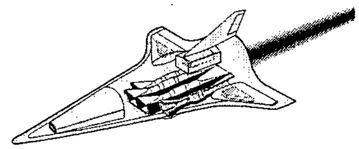
Goals

- Fulfill Identified TMD and NMD System Requirements
- Identify, and Resolve Plume Technology Deficiencies
- Transition the Use of Plume Technology From Developers to Users
- Provide Timely System Support and Consultation to BMDO/AF Programs

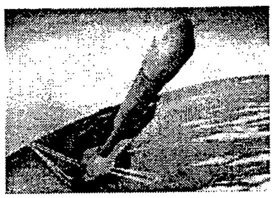
Revolutionary Propulsion Technology

High energy-density matter (HEDM)

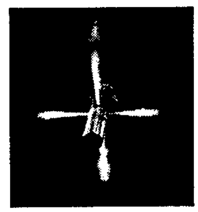


Plasma-assisted drag reduction and combustion enhancement (Ajax)



Low-cost pulsed-detonation propulsion (PDP)

Laser propulsion



Micropropulsion

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